Mercury bioaccumulation in the Tambopata River, Peru: a food web perspective

Katherine A. Roach, Christine Fiorello *, Nicolas F. Jacobsen & Kirk O. Winemiller

Texas A&M University, University of California*

APPLIED BIODIVERSITY SCIENCE
Bridging Ecology, Culture, and Governance for Effective Conservation

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Abstract

We measured inorganic mercury and methylmercury concentrations and trophic positions of six fish species that are important food resources for humans and the giant otter *Pteronura brasiliensis* in the Tambopata River, Peru and a connected oxbow lake. Additionally, we estimated inorganic mercury concentrations of sediment and water-column and benthic respiration, net primary production, and gross primary production in each habitat to begin to determine how mercury bioconcentration is related to food web structure. Inorganic mercury concentrations in fishes ranged from 24 – 345 ng Hg/dry weight of tissue, and methylmercury concentrations ranged from 2010 – 6410 ng Hg/dry weight of tissue. Inorganic mercury concentrations of sediments were higher in the lake, however fishes from the main channel generally had higher mercury concentrations. The main channel may be more prone to mercury biomagnification than Tres Chimbadas lake because of its heterotrophic nature (water-column net primary production was zero), or because inorganic mercury from gold mining is not entering Tres Chimbadas lake due to its protected status.

Introduction

Mercury is a pollutant that can result in developmental and behavioral abnormalities, impaired reproduction, and decreased survival in vertebrates (Sweet and Zelikoff 2001). Methylmercury is the form of most concern because it bioaccumulates. The U.S. Environmental Protection Agency (EPA) recommends that fish with methylmercury concentrations over 0.3 mg/kg fish tissue should not be consumed by humans. Methylmercury concentrations in fishes are known to be influenced by ambient methylmercury concentrations in water and sediment, food web structure, and the presence of sulfate-reducing bacteria which can transform inorganic mercury to methylmercury under anoxic environmental conditions (Morel et al. 1998).

In the Madre de Dios department, Peru, gold mining is a common economic activity and is believed to have contributed to increased inorganic mercury concentrations in the water and sediments of some rivers (Goulding et al. 2003). This is of concern for local people and giant otters (*Pteronura brasiliensis*) because their diet is based on fish.

We measured inorganic mercury and methylmercury concentrations in six fish species that are important food resources for humans and the giant otter in the Tambopata River, Peru, and the connected oxbow lake Tres Chimbadas to determine if mercury levels were above those recommended as unsafe by the EPA. We have observed gold mining occurring in the main channel, however the oxbow lake has been designated as a conservation reservation by the local community of Infierno thus neither mining nor fishing for consumptive purposes occurs. Additionally, we compared mercury and methylmercury levels with trophic positions of fishes, inorganic mercury concentrations of sediment, and water-column and benthic respiration, net primary production, and gross primary production estimates from each habitat to better understand the biomagnification process.

Fig. 1. The two study systems in southeastern Peru where this study was conducted. Tres Chimbadas is an oxbow lake connected to the Tambopata River via a small creek.

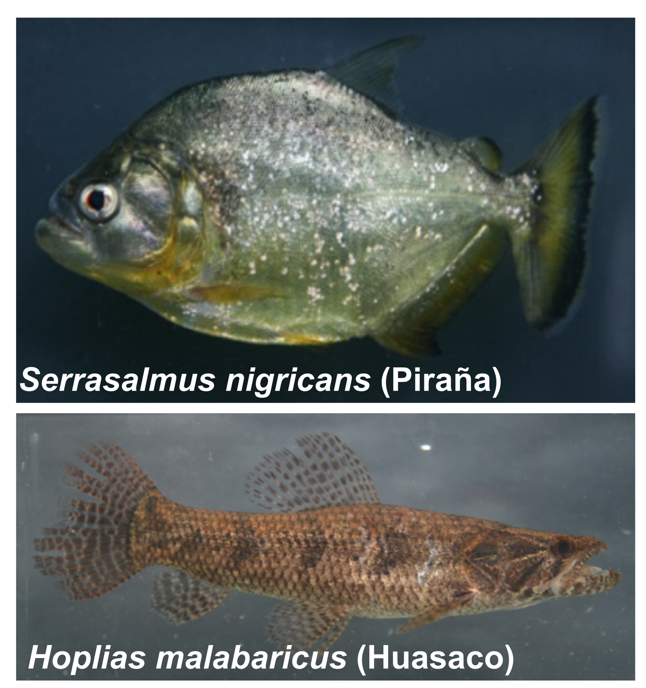

Fig.2. The six taxa considered in this study. Species on the left were captured in the lake and species on the right were captured in the main channel.

Methods

Sample collections

Fish species that were important food resources were determined from Groenendijk and Hajek (2006) for giant otters and by informal interviews and personal observations of local people (KAR). Fishes were collected from the lake and main channel from May to August 2009 with seines, cast nets, and hook and line. Muscle samples were taken from the dorso-lateral region and preserved for stable isotope and mercury analysis. Sediment and production sources including seston, benthic algae, and macrophytes were also collected from each habitat and preserved for stable isotope analysis.

Mercury concentrations

Sediment and fish muscle samples were sent to the Quicksilver Scientific Laboratory in Lafayette, Colorado for high pressure liquid chromatography speciation analysis of inorganic mercury and methylmercury. A conservative conversion factor of 8 was used to convert dry weight to wet weight.

Trophic position

Fish and production source samples were sent to the University of Kansas for stable isotope analysis. Trophic position estimates were based on fractionation of $\delta^{15}N$ between fishes and production sources. The trophic position of each individual was calculated as $TP = [(\delta^{15}N_{consumer} - \delta^{15}N_{reference})/2.54] + 1$.

Ecosystem metabolism

Light and dark chambers were used to estimate respiration (R), gross primary production (GPP), and net primary production (NPP) of the water-column and benthos in the lake and main channel following Suplee and Cotner (2002). For water-column metabolism, six 300 mL light and six dark biological oxygen demand (BOD) bottles were incubated at approximately 0.7 m depth. For benthic metabolism, four circular Plexiglass benthic chambers, each with a propeller to gently mix water, were pressed into the sediment to enclose the substrates. DO concentrations were measured before and after incubations.

Results

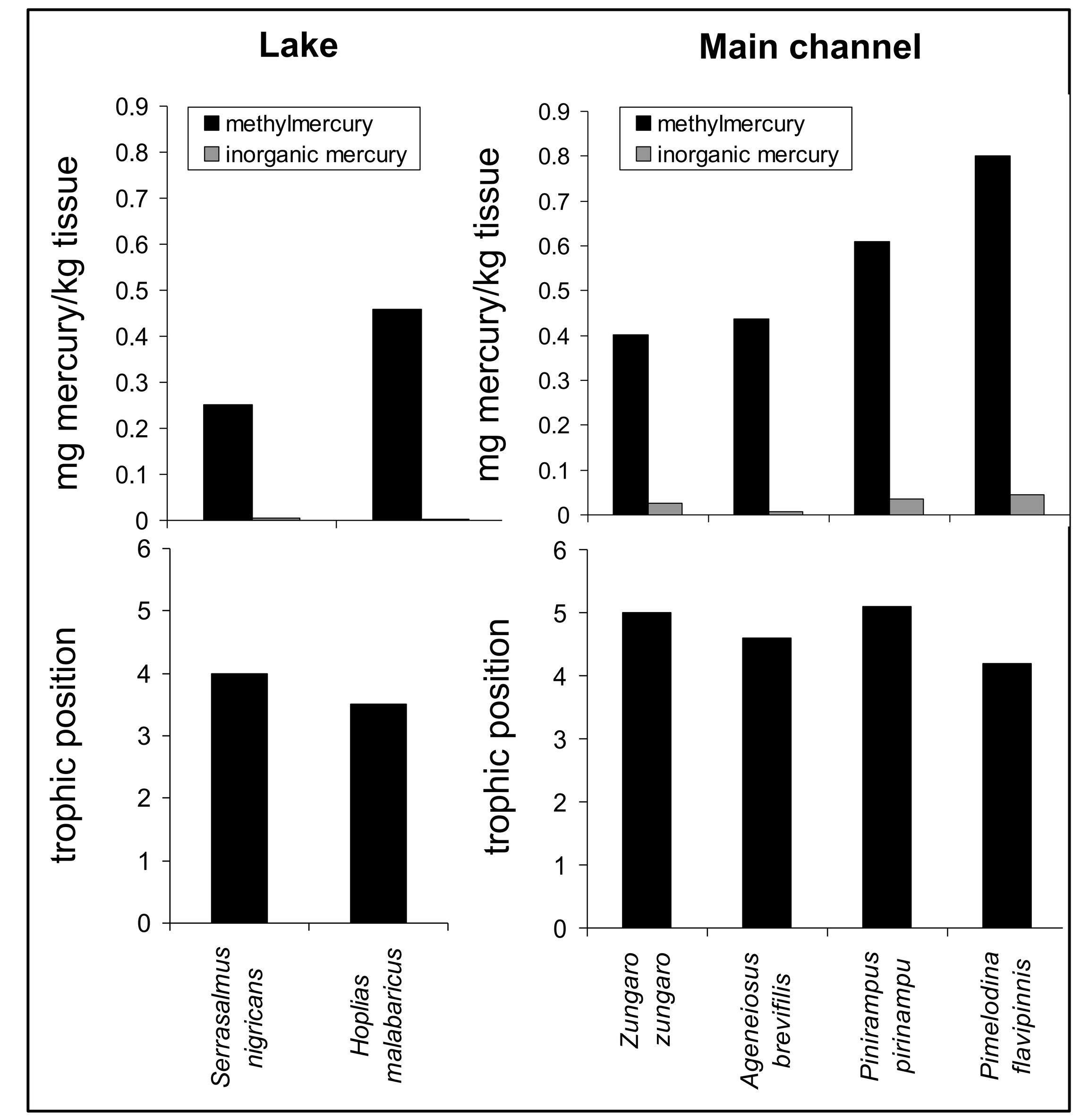

Fig.3. Methylmercury and inorganic mercury concentrations and trophic positions of fishes from the lake and main channel. Total length of *Serrasalmus nigricans* = 92.7 cm; *Hoplias malabaricus* = 26.5 cm; *Zungaro zungaro* = 92.7 cm; *Ageneiosus brevifilis* = 50.8 cm; *Pinirampus pirinampu* = 68.6 cm; and *Pimelodina flavipinnis* = 64.8 cm.

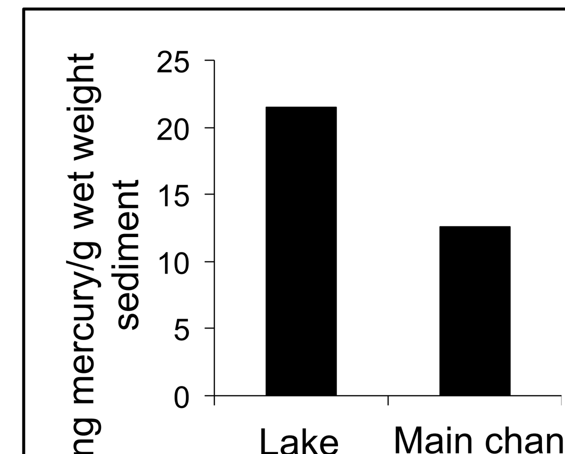

Fig.4. Inorganic mercury concentrations of sediment from the lake and main channel.

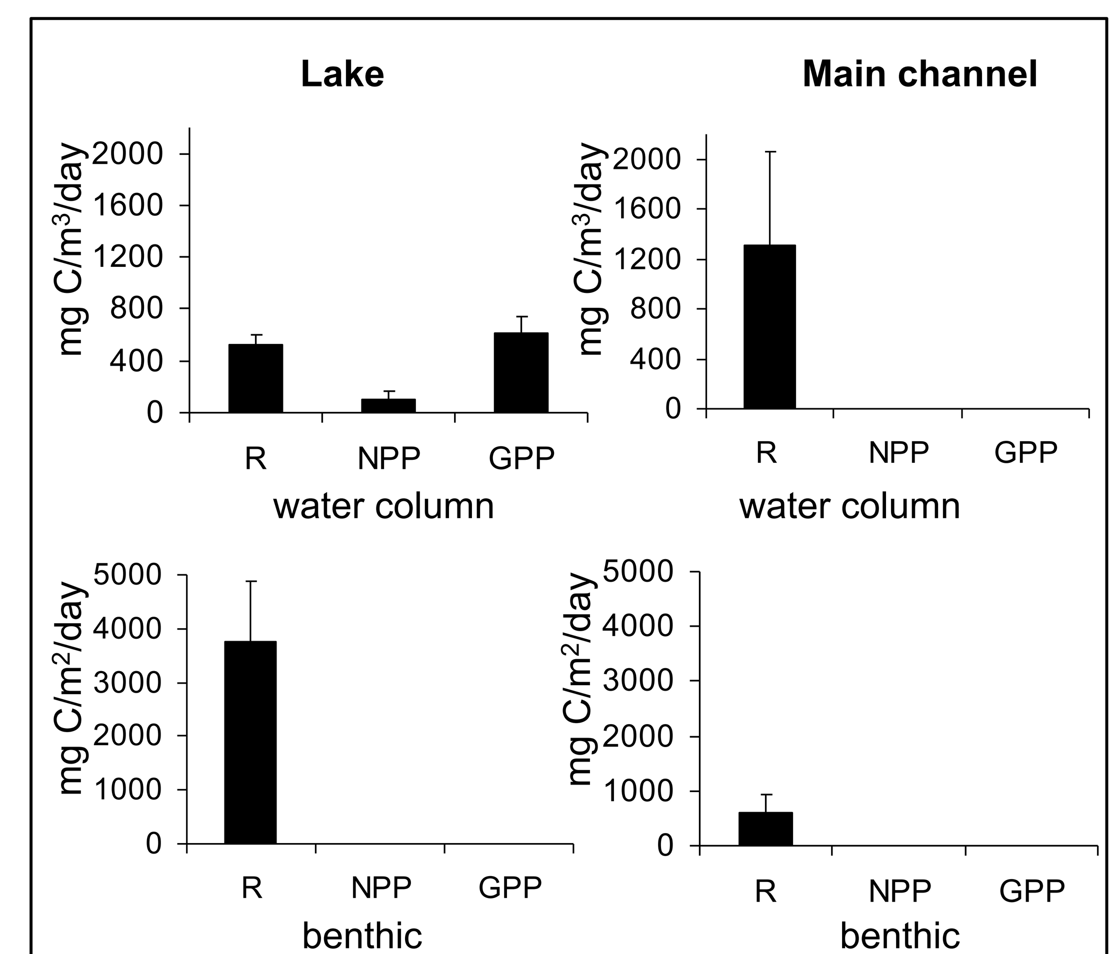

Fig.5. Mean (+1 SE) respiration (R), net primary production (NPP), and gross primary production (GPP) at lake and main channel sites.

Conclusions

- Fishes from both the lake and the main channel had inorganic mercury concentrations higher than those recommended for consumption by the EPA.
- The fishes from each habitat that had the highest methylmercury and inorganic mercury concentrations were not feeding at the highest trophic positions. For example, *Pimelodina flavipinnis* had methylmercury concentrations two-fold higher than *Zungaro zungaro*, however *Zungaro zungaro* fed at a higher trophic position.
- The inorganic mercury concentration of sediment from Tres Chimbadas was higher compared to the Tambopata River main channel, however fishes from the main channel generally had higher methylmercury and inorganic mercury concentrations.
- Benthic R was six-fold higher in Tres Chimbadas compared to the main channel; sediments were likely anoxic.
- Phytoplankton was virtually nonexistant in the main channel water column. Other studies have shown that oligotrophic ecosystems (i.e. those with low net primary production) often have greater bioconcentration of contaminants compared to eutrophic ecosystems (i.e. those with high net primary production; Gilmour et al. 1998). Greater biomass of prokaryotic heterotrophs compared to algae may facilitate contaminant bioaccumulation through the food chain (Cotner et al. 2002).
- The Tambopata River main channel may be more prone to mercury biomagnification than Tres Chimbadas lake because of its heterotrophic nature, or because inorganic mercury from gold mining is not entering Tres Chimbadas lake due to its protected status.

Future research

- This summer we will sample inorganic mercury and methylmercury concentrations in fishes, their trophic positions, R, NPP, and GPP, and ambient inorganic mercury and methylmercury concentrations in habitats of the heavily mined Inambari River.
- Besides focusing on fishes that are important to local people and giant otters, we will estimate mercury concentrations in non-migratory Loricariid catfish in the Tambopata River and Inambari River in order to examine habitat-specific differences in mercury concentrations.
- We will attempt to estimate mercury concentrations and trophic positions of giant otters using fur samples (e.g. York and Billings 2009).
- The diets of local people will be more closely examined from surveys and interviews of fishermen selling to markets.

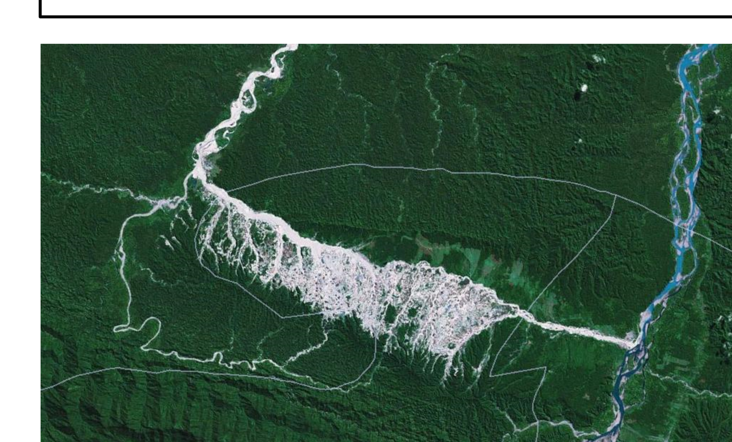

Fig.6. Google earth image of damage caused by gold mining to the Inambari River, Peru.

Acknowledgements: Amanda Stronza, Andrew Jackson, David Flores, Hernan Ortega, Kurt Holle and other Rainforest Expeditions employees, Rob Williams and Larissa Silva from Frankfurt Zoological Society.